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PALEONTOLOGICAL RESOURCES TECHNICAL LETTER REPORT
(EVG WYDOT 1-8-2013)

Project: Non-field paleontological evaluation of proposed United States Highway 14 (US 14) landslide reroute project, about 3 miles west of Sundance, Wyoming.

Project/Location: Sections 17–20, T51N, R63W

Project Description: The project includes reconstructing and relocating a section of road and options for removing a large landslide area. The project is needed to ensure long term mobility and safety on US 14 in the vicinity of Rupe Hill. Safety and mobility are compromised by the landslide which began causing damage to the roadway May 2011.

Summary of Results/Recommendations:

Company Contacts: Ms. Laura Lutz-Zimmerman, Project Manager, HDR Engineering, Inc (Denver).

Paleontological Principal Investigator: Gustav F. Winterfeld, PhD, Principal Scientist with Erathem-Vanir Geological (EVG).

Work Conducted/Personnel/Permit: At the request of Ms. Lutz-Zimmerman, Dr. Winterfeld conducted non-field paleontological evaluation of the proposed alternative highway routes. Geological mapping by Sutherland (2007) showing the underlying bedrock beneath the proposed ROW is provided in Figure 1.

Dr. Winterfeld, the PI for the project is a Registered Wyoming Professional Geologist (PG-2224) with 35 years field experience and is considered an expert in the paleontology and geology of the Western US. As a qualified and permitted paleontologist for the BLM and other agencies, he has directed and performed literature and record reviews and conducted field geological and paleontological surveys for projects including coal mines, trona mines, pipelines, dam sites, flood control projects, gravel pits, housing developments, transmission lines and well pads. As part of his work, he has analyzed environmental impacts to fossil resources and recommended and implemented mitigation and resource recovery programs for paleontological resources for clients including federal (BLM, BOR, FERC, DOE, USDA-USFS), state and local government agencies, and private companies.

GEOLOGY AND PALEONTOLOGY

Surficial Geology

Although paleontological and geological field survey has not been conducted by the PI for this report, a WYDOT (2012) report on the project area discusses the surface geology in the vicinity of the proposed alternatives. The report documents the presence of thick colluvium/landslide debris and landslide masses along both sides of US14.

The particular landslide of concern, the Rupe Hill Landslide, according to WYDOT is located at M.P. 197.4, about three miles west of Sundance, Wyoming, on US 14. The landslide is 1,000 feet wide at the highway and extends 500 feet left of centerline and 1,000 feet right of centerline, making this one of the largest landslides affecting a highway in Wyoming. The landslide mass is a reactivated complex block failure mapped by the Wyoming State Geological Survey (WGS). Material comprising the Rupe Hill Landslide includes as much as 70 feet of slide debris/colluvium that unconformably overlies shale bedrock belonging to the Sundance Formation of Jurassic age.

In addition to the Rupe Hill Landslide, several other landslide masses have been mapped (WSGS 2001) along both sides of the state highway.

A photograph included in the WYDOT geology report taken along the highway shows the terrain vegetated with few, if any, bedrock outcrops. Satellite photos suggest that almost all, if not all, of the proposed alternatives is underlain by colluvium and regolith derived from weathering of underlying bedrock formations and devoid of bedrock outcrops. The depth to bedrock is undoubtedly variable, but actual thickness is unknown.

Bedrock

Bedrock geology underlying the project area is provided by Sutherland (2007) and depicts both alternatives as being underlain by bedrock of Jurassic and early Cretaceous age (Figure 1). Underlying bedrock units include, in stratigraphic order from youngest to oldest, the following

- Inyan Kara Group
- Morrison Formation
- Sundance Formation
- Gypsum Springs Formation

The Inyan Kara and Morrison formations are not separately mapped but instead lumped as KJ. Likewise the Sundance and Gypsum Springs formations are not separately mapped but lumped as Jsg. The northern alternative is underlain to the east by Jsg and the west by KJ. The southern alternative is underlain by Jsg on both its eastern and western ends by and in the center by KJ. The fact that these formations were not mapped separately strongly suggests the lack of extensive bedrock outcrops at the surface.

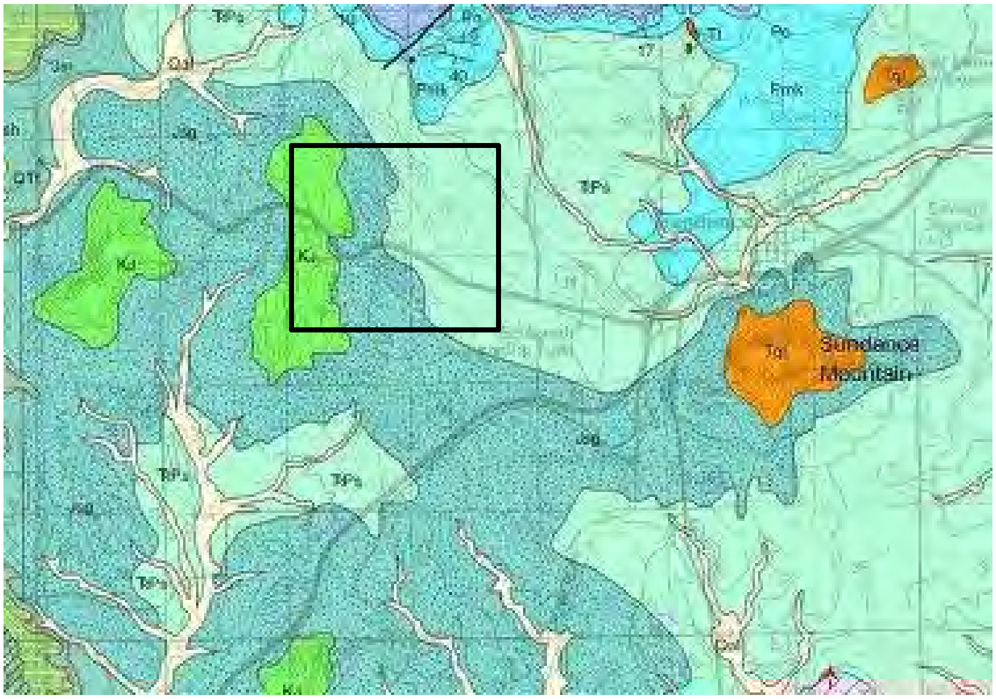

Figure 1. Bedrock Geology of the Project Area (general areas shown inside box)

Source: Geology from Sutherland 2007.
KJ in bright green = Inyan Kara and Morrison Formations
Jsg in stipple blue green = Sundance and Gypsum Springs Formation.

Inyan Kara Group

Geology

Darton (1899, 1901) recognized that the rocks of the Black Hills could be divided into a lower sandstone and conglomerate unit he named the Lakota Sandstone, an intermediate variegated shale and mudstone unit he named the Fuson Shale, and an overlying iron-stained sandstone unit that he incorrectly referred to the Dakota Sandstone of Meek and Hayden (1862). The discovery of Lower Cretaceous age fossil plants in the upper iron-stained sandstone unit induced Russell (1927) to substitute the name Fall River Sandstone for the age inappropriate Dakota Sandstone misnomer. Russell (1927) also recognized a sporadically occurring limestone unit between the Lakota and Fuson that he named the Minnewaste Limestone.

The Inyan Kara Group was named for exposures along Inyan Kara Creek in the northeastern part of the Powder River basin Moorcroft, Wyoming, U.S. Geological Survey quadrangle. The type area 150-foot- to 350-foot-thick Inyan Kara Group includes the uppermost Fall River Sandstone, the underlying Fuson Shale, and the basal Lakota Sandstone. This highly variable group comprises discontinuous beds of sandstone, sandy shale, conglomerate, lignite, and variegated siltstone. In general, though not in detail, the higher slab-bedded sandstones of the Inyan Kara are more heavily iron-stained, and the lower sandstones are a lighter gray and massive (Ruby, 1931). Waage (1959) reduced the Fuson Shale and the Minnewaste Limestone to member status within a redefined Lakota Formation. The Chilson Member was named as part of the Lakota Formation by Post and Bell (1961) for exposures in Chilson Canyon, Fall River County, South Dakota, where it is 250 feet (75 meters) thick.

In the southern Black Hills of South Dakota and Wyoming, the Cretaceous-age Inyan Kara Group is 135 feet to 900 feet thick and consists of the Lakota Formation and overlying Fall River Formation. In this region, the Lakota Formation includes the Chilson, Minnewaste Limestone, and Fuson Shale Members (Carter and Redden, 1999). The Lakota Formation consists of a yellow, brown, and reddish-brown massively to thinly bedded sandstone, pebble conglomerate, siltstone, and claystone of fluvial origin with local lenses of limestone and coal (Dandavati and Fox 1981).

The Chison Member includes two conspicuous fluvial sandstone bodies stratigraphically separated by an intervening greenish-gray mudstone unit (Post and Bell 1961). The intermediate Minnewaste Limestone Member, where present, overlies the Chilson Member and is a fine-grained limestone of lacustrine origin. The overlying Fuson Member consists mostly of red, green, and gray siltstone and mudstone (that may be more or less lacustrine in origin), with interbedded sandstones (Gott, et al. 1974). The Fall River Formation is a brown to reddish-brown, fine-grained sandstone, thin bedded at the top and massive at the bottom (Strobel, et al. 1999).

Although not mapped separately in the project area by Sutherland (2007), the Inyan Kara Group includes the Fall River Formation and Lakota Formation.

According to Sutherland (2007), the Fall River Formation comprises two distinctive upper and lower units. The upper unit consists of 10 feet to 30 feet of thin-bedded, nonresistant siltstone, sandstone, and shale, which is underlain by one or more resistant massive to subtly cross-bedded layers of well-sorted, fine to very fine grained friable, tan-weathering sandstones that form ledges and cliff at the top of ridges and are locally persistent.

The lower part of the Fall River Formation consists of about 60 feet to 65 feet of mostly nonresistant, dark-gray silt shale, siltstone, thinly interbedded with yellowish-light gray, fine grained sandstone and siltstone.

The Lakota Formation consists of between 45 feet and 300 feet of complexly interfingering and lenticular beds of sandstone, siltstone, and claystone. The sandstone is well-sorted, fine- to coarse-grained, locally cross bedded and occasionally conglomeratic. Claystone in the formation is locally interbeded with coal, carbonaceous shale, and limestone lenses. The formation is varicolored in tones of brown to gray, reddish- to yellowish-brown, yellow and occasionally green, with red and purple in some areas near the top.

Paleontology

Fragmentary fish, turtle, and crocodile remains (Grace, 1955), and partial skeletons and skulls attributed to the ornithopod dinosaurs *Iguanodon lakotaensis* and *Camptosaurus depressus*, and the ankylosaur *Hoplitosaurus marsh* have been reported from the Lakota Formation of the Inyan Kara Group (Lucas, 1901, 1902; Gilmore, 1909; Weishampel and Bork; 1989; Weishampel and others, 2004). Theropod dinosaur tracks were reported from the Lakota Formation by O'Harra (1917) and Anderson (1939). The Lakota Formation may also preserve the oldest known tracks of large quadrupedal ornithopod dinosaurs (Lockley and others, 2001). No fossils except for permineralized fossil wood have been reported from the Minnewaste Member of the Lakota (Grace, 1955).

Ward (1899, 1905), Wieland (1906, 1916), Cahoon (1960), and Delevoyas (1971) have recognized and described early Cretaceous gymnosperm conifers, cycads, ginkos, and ferns from the Lakota. According to Retellack and Dilcher (1986), however, the oldest angiosperm plant fossils in the Inyan Kara Group are rare and limited in diversity. They include monosulcate pollen grains (Davis, 1963) and leaves dominated by *Sapidopsis* from the Fuson Shale (Ward, 1899). Microorganisms have also been recognized in the Fuson (Bradley, 1924). A marine influence is indicated by the mangal fern *Weichselia* in the upper Lakota Formation (Fontaine in Ward, 1899). At some localities in the Fall River Formation], angiosperm leaves are common (Ward, 1899). The Fall River Formation also harbors the oldest tricolate pollen in the region (Davis, 1963). Other fossil plants are less common in the Fall River, and cycads and *Weichselia* are absent.

Morrison Formation

Geology

The upper Jurassic age Morrison Formation (*KJs*) is found in twelve U.S. states and three Canadian territories: Alberta, Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Manitoba, Oklahoma, Saskatchewan, South Dakota, Texas, Utah, and Wyoming (Turner and Peterson, 1999, Figure 1). It was named after the town of Morrison in Jefferson County, Colorado, at the very foot of the Rocky Mountains just west of Denver (Eldridge, 1896). Forty-eight years later, a Morrison Formation type section was designated along the north side of West Alameda Parkway on the western slope of a hogback road—cut about two miles north of Morrison (Waldschmidt and LeRoy, 1944). The Morrison Formation is predominantly made up of sandstone and mudstone. It also incorporates a variety of additional lithologies including conglomerate, claystone, tuff and bentonite beds, limestone, dolomite, gypsum, anhydrite, and coal (Turner and Peterson, 1999).

At least 16 formally named (and generally regionally confined) Morrison Formation members (listed below) have been proposed. The working definition of a given member may have also been subsequently reinterpreted by geographically removed workers. The list of formally proposed and modified Morrison member names currently deployed in the literature includes: the Bluff Sandstone, Brushy Basin, Bullington, Casamero, Chavez, Fiftymile, Jackpile Sandstone, Junction Creek, Prewitt Sandstane, Recapture, Salt Wash, Stockett Bed, Tidwell, Unkpapa Sandstone, Westwater Canyon, and Windy Hill Members (see Darton, 1904; Burbank, 1930; Goldman and Spencer, 1941; Cobban, 1945; LeRoy, 1946; Imlay, 1947; Stokes and Phoenix, 1948; Eckel, 1949; Harshbarger and others, 1951; Smith, 1954**;** McLaughlin, 1954; Freeman and Hilpert, 1957; Ekren and Houser, 1959; Moberly, 1960; Mirsky, 1962; Smith, 1967; O'Sullivan, 1980, 1983, 1984; Szigeti and Fox, 1981; Mudge and Rice, 1982; Owen and others, 1984; Aubrey, 1988; Condon and Huffman, 1988; Peterson, 1988; Condon, 1989; Lucas, 1991; O'Sullivan, 1992; and Peterson, 1994, for more details).

The Morrison Formation sits between the overlying Cloverly or Lakota Formations and the underlying Sundance Formation in Wyoming. In southeast, central, north-central, and northeast Wyoming, the Upper Brushy Basin Member and the Lower Brushy Basin Member typically overlie the Windy Hill Member (Turner and Peterson, 1999, Figure 5 and Figure 6). These two Morrison Formation members comprise inter-bedded, dully variegated claystone, nodular limestone, and gray silty sandstone (Love and Christiansen, 1985) that is generally divisible into three informal stratigraphic zones, according to DeCelles and Burden (1992): (1) a lower sandstone, deposited by a complex coastal dune-foreshore-fluvial system as the Sundance seaway regressed, (2) a middle mudstone, deposited by muddy fluvial and ephemeral lacustrine systems during a prolonged period of regional, seasonal aridity, and (3) an upper sandstone, deposited by a sandy fluvial system of variable sinuosity.

According to Southerland (2007), the Morrison Formation reaches up to 150 feet thick but may be absent in some areas, consists of a sequence of light greenish-gray to greenish-pink and grayish-red siltstone and claystone, along with thin, lenticvular light-gray sandstones and shaly limestones. The upper part of the formation is darker colored and noncalcareous, whereas the lower part is light colored and calcareous.

Paleontology

The first major vertebrate paleontological discoveries in the Morrison Formation of Wyoming and Colorado were made in the 1870s (Ostrom and McIntosh, 1966; Breithaupt, 1998). Today, this upper Jurassic formation is still a major locus for extensive scientific collecting and analysis, and its perennially popular, seemingly larger than life megafauna is one of the most well-known in the world. Evidence of prehistoric life preserved in the Morrison Formation includes fossil wood (Delevoryas, 1960), the shells of snails and freshwater unionid clams (Branson, 1935; Yen and Reeside, 1946; Engelman 1999), and the scattered skeletal parts of mammals, turtles, pterosaurs, and dinosaurs up to and including hundreds of excavated skeletons, some of them partial, some of them complete (Chure and others, 1998).

Turner and Peterson (1999, Appendix 1) list 60 institutionally recognized dinosaur-producing sites in nine different areas of Wyoming: the Natrona County Alcoa area (4), the Crook County Black Hills northwest area (5), the Albany and Carbon County Como Bluff area west of Marshal Road (17), the Albany County Como Bluff area east of Marshal Road (9), the Big Horn County Graybull-Shell area (4),the Johnson County Kaycee area (4), the Albany and Carbon County Medicine Bow (a.k.a. Flat Top) anticline area (9), the Albany County Sheep Creek area (2), and the Hot Springs County Thermopolis area (6).

The primary producing layer of the Bighorn basin Howe Quarry of the American Museum of Natural History (AMNH) is somewhere between 145 (Swierc and Johnson, 1996) to 152 (Turner and Peterson, 1999) million years old. In 1934, AMNH field crews quarried and removed 30 metric tons (33 U.S. tons) of bones that were crated up and loaded onto trains bound to New York City where the museum is located (Brown, 1935; Colbert, 1968). Measuring 14 meters by 20 meters at that time, Howe Quarry revealed what is still regarded as one of the densest concentrations of Jurassic dinosaur bones ever found. This Morrison Formation accumulation of drought-desiccated carcass parts was washed by a flood-event into a river levee waterhole. At least 25 individual sauropod dinosaurs are partially represented

(Breithaupt, 1997; Michelis, 2001). The fauna is dominated by the sauropod *Barosaurus*. *Apatosaurus*, *Camarasaurus*, and *Camptosaurus* and are also present. Adults and several juvenile to subadult individuals are represented by partial skeletons that decrease in size towards the periphery of the fossil bed and range from about 50 percent complete to completely disarticulated (Michelis, 2001).

Isolated theropod teeth, sauropod skulls, claviculae, sternal ribs, carbonised skin impressions, and gastroliths (dinosaur-sized gizzard stones) were also collected at Howe Quarry by the AMNH (Brown, 1935; Michelis, 2001). Howe Quarry has been subsequently worked by various institutions. Lockley and others (1998) described several theropod tracks in the new part of Howe Quarry that represent two medium- to large-sized theropods (47 centimeters and 43 centimeters footprint lengths) and a small theropod (12 centimeters). The most complete *Allosaurus* found to date was exhumed about 300 meters northeast of historic quarry site (Laws, 1996). Siber Quarry, located about 200 meters southwest of the historic quarry, has been worked by a private collector (whose base of operations is in Switzerland) for more than a decade. Saurischian sauropod (5) and theropod (1) dinosaurs, and ornithischian stegosaur (1) and ornithopod (1) dinosaurs have been recognized at Siber Quarry (Wilborn, 2001).

Fish (1), salamanders (2), and frogs (1) are known from the Como Bluff Quarries. Recognized reptiles include saurischian sauropod (9) and theropod (8) dinosaurs, ornithischian ornithopod (11) and stegosaur (6) dinosaurs, winged pterosaurs (1), crocodilians (2), turtles (4), and lizards (1). One Como Bluff bird species has been described. Recognized Como Bluff mammals include multituberculates (6), symmetridonts (4), pantotherians (19), and docodonts (6) (Ostrom and McIntosh, 1966).

In a more recent species count that focused exclusively in Como Bluff Quarry 9, species belonging to the following groups were recognized by Carrano and Velez-Juarbe (2006): an unidentified aquatic freshwater charophyte plant (1), snails (2), freshwater bivalves (1), fish (3), salamanders (4) and frogs (2) (Evans and Milner, 1993), turtles (2), lizards (2), rhynchocephalians, an order of mostly extinct lizardlike reptiles that only includes the tuatara today (2), champsosaurs (Order Choristodera) that resembled modern gavials (1), crocodiles (2), dinosaurs that include saurischian theropods (6) and sauropods (2) and ornithischian ornithopods (3) and stegosaurs (1), pterosaurs (1), and mammalian docodonts (5), multituberculates (6), triconodonts (7) symmetrodonts (2) and dryolestids (15) as well.

The lithology and sedimentology of the Quarry 9 setting and the fragile, disarticulated nature of most of this skeletal debris is consistent with low-energy conditions found in ponds or abandoned oxbow floodplain channels. An abundance of aquatic charophyte plants denotes a clear, well-oxygenated aquatic environment in which amphibious crocodilians and turtles could numerically flourish under low energy depositional conditions. The associated mix of diminutive mammals, small reptiles, and conspicuous consumption dinosaurs in the terrestrial food web is much more diverse and significantly less populous (Carrano and Velez-Juarbe, 2006).

More than 200 individual trackways that collectively display at least 12 morphotypes, have been recognized at more than 50 sites in the Morrison Formation. These tracksites, more commonly seen in the lower half of the formation, have been attributed to turtles, crocodilians, pterosaurs, theropods, sauropods, onithopods, stegosaurs, and lizards (Foster and Lockley, 2006). Near Rock Creek, west of Quarry 13 in the eastern Como Bluff area, the tracks of several theropods and sauropods as well as possibly ornithopod morphotypes occur as impressions in a thin limestone unit with at least 28 exposed tridactyl (probably theropod) trackways (Southwell and others, 1996).

A recently discovered Morrison Formation tracksite in the Bighorn Basin, Wyoming, displays abundant sauropod tracks. Most of these footprints are indistinct bulges on the bottoms of sandstone beds. Several, however, are well preserved and show foot pad and skin impressions. Three track morphotypes are recognized: a sauropod pes (hind foot) print, a *Brontopodus*-like manus (forefoot) print, and a diplodocid manus (forefoot) print. The *Brontopodus*-like print most likely represents the manus of a brachiosaur, showing for the first reported time a sauropod phalangeal node. The unique diplodocid manus print contains impressions of a substantial ungual on digit I and a heel pad. Another partial sauropod track cast is only the second known North American sauropod footprint that displays skin impressions of interlocking, polygonal scales (Platt and Hasiotis, 2006).

Larger upper Jurassic Morrison vegetation, chiefly conifers (Ash and Tidwell, 1998), was primarily confined to riparian areas. Turner and Peterson (2004) infer a shaded understory and groundcover consisting of shrubs and smaller plants (flourishing where evapotranspiration rates were somewhat lower due to the cooler temperatures) that probably consisted of the ginkgophytes, cycads, tree ferns, horsetails, and the various of ferns that have been reported from the formation (Ash and Tidwell, 1998; Chin and Kirkland, 1998). Morrison Formation mudstone and limestone beds in and around Cañon City, Colorado, comprise a riparian flora assemblage that fits this description: algae, bryophytes, ferns, ginkgophytes, horsetails, cycads, bennettites, and conifers. The associated faunal assemblage includes ostracodes, conchostracans, aquatic insect larvae traces, a terrestrial insect body fossil, prosobranch and pulmonate gastropods, several fish species, a possible frog, and rare turtle remains (Gorman and others, 2008).

Six plant taphofacies: wood, whole-leaf, leaf-mat, root, common carbonaceous debris, and rare carbonaceous debris are represented in the Morrison Formation. None of these taphofacies is common in the Morrison. The paucity of wood is sometimes striking, even in more reducing environments. The flora of the Morrison Formation is more distinct in the Kimmeridgian and Tithonian parts of the section. The six plant taphofacies are consistent with a predominantly herbaceous vegetation. Various lines of evidence from the plant taphofacies, floras, and sedimentology of the Morrison Formation are consistent with a warm, seasonal, semi-arid climate that changed from dry semi-arid to humid semi-arid over the Kimmeridgian to Tithonian transition (Parrish and others, 2004).

Sundance Formation

Geology

The Sundance Formation was first recognized by Darton (1899), who failed to explain the derivation of the name or designate a type area. This formation was probably named for the town of Sundance in Crook County, Wyoming. A standard principal reference section was later established in section 3 of T06N,R02W of Lawrence County, South Dakota (Imlay, 1947, 1980).

The Sundance has been recognized in the Big Horn basin, the Central Montana uplift, the Chadron arch, the Denver basin, the Green River basin, the Montana folded belt province, the North Park basin, the Powder River basin, the Sioux uplift, the Uinta basin, the Williston basin, and the Wind River basin regions of seven states: Colorado, Idaho, Montana, Nebraska, South Dakota, Utah, and Wyoming. Recognized members embraced by the Sundance Formation (listed alphabetically) include the Canyon Springs Sandstone Member (CO, MT, SD, WY), the Hulett Sandstone Member (MT, SD, WY), the Lak Member (CO, MT, SD, WY), the Pine Butte Member (CO, SD, WY), the Redwater Shale Member (CO, MT, SD, WY), and the Stockade Beaver Member (MT), also known as the Stockade Beaver Shale Member (SD, WY).

Overall, the Sundance Formation consists of an alternating sequence of greenish-gray shale, light-gray to yellowish-brown sandstone and siltstone, and gray limestone. The formation crops out above the gypsum and red shale of the Gypsum Spring formation on the bluffs and low rolling hills that surround Devils Tower. Four members are recognized in this area. They are, in order of age from oldest to youngest, the Stockade Beaver, the Hulett Sandstone, the Lak, and the Redwater Shale members.

The Stockade Beaver Member is 85 feet to 100 feet thick and generally consists of gray-green shale with interbedded fine-grained calcareous sandstone. The Hulett Sandstone Member is a massive fine grained glauconitic calcareous sandstone unit. Ranging from 60 feet to 70 feet thick in the Devils Tower area, the Hulett is typically yellow or brownish-yellow but locally may be pink or red. The Lak Member is composed of poorly bedded soft, very fine-grained calcareous sandstone and siltstone with a few thin gray-green sandy shale partings. About 45 feet thick on average, the Lak Member usually weathers into gentle slopes covered with vegetation. Ranging in thickness from 150 fee to 190 feet, the Redwater Shale Member consists mostly of light-gray to dark gray-green soft shale, with beds of yellow soft sandstone in the lower part of the member and lenticular beds of fossiliferous limestone up to four feet thick in the upper part (Imlay, 1947, Robinson, 1956).

Paleontology

Although plesiosaur material from the Redwater Shale Member (Jurassic, Oxfordian) of the Sundance Formation had been known for more than 100 years, much of it was only finally referred to the long-necked cryptocleidoid plesiosaur *Pantosaurus striatus* by Okeefe and Wahl in 2003. O.C. Marsh described *Pantosaurus striatus* in 1893. A recent bone density study noted that 7 out of 10 cryptocleidoid plesiosaurs from the Redwater Shale Member of the Sundance Formation of Natrona County exhibited juvenile bone density characteristics (Wahl, 2006).

Massare and others (1999) briefly described an unprepared ichthyosaur (a fish-like finned marine reptile) from the Redwater Shale that was found in Natrona County, Wyoming. The specimen includes an articulated skull and lower jaw, the anterior half (at least) of the vertebral column, the pectoral girdle, and numerous ribs. The polydactyl hindlimbs and forelimbs had been lost. The specimen was subsequently referred to *Ophthalmosaurus natans* (Massare and others, 2006).

Soft-shelled decapod shrimp (Herrick and others, 1978), clams, oysters, and the cuttlefish relative *Belemnites densus* are also known from the Sundance of Wyoming (Robinson, 1956). Fossil tracks of the pterosaur ichnospecies *Pteraichus stokesi* are known from the Alcova/Grey Reef Reservoir, the Seminoe Reservoir, and the Bighorn Canyon National Recreation areas of Wyoming (Jennings and Hasiotis, 2006; Lockley and others, 2008).

Gypsum Springs Formation

Geology

The Middle Jurassic (early to middle Bajocian) Gypsum Spring Formation crops out sporadically for a distance of about 150 miles along the western and northern flanks of the Black Hills in northeastern Wyoming and west-central South Dakota. The formation is about 125 feet thick at its most northwestern exposure 10 miles northeast of Hulett, Wyoming, where it consists of a lower sequence of massive gypsum and red claystone about 75 feet thick, and an upper sequence of interbedded light gray limestone and red and gray claystone about 50 feet thick. The formation thins irregularly southward and eastward as a result of truncation by the overlying Sundance formation of Late Jurassic age (Mapel and Bergendahl, 1956, (Whitcomb and Morris, 1964).

Love (1939, 1940) named what is now known as the Gypsum Spring as the upper member of Chugwater formation for a gypsum spring on Red Creek in the southeastern Washakie Range, Fremont County, part of Wyoming's Wind River basin. No type locality was designated. Measured sections in section 36, T7N R4W, section 1, T6N, 4W, and section 6, T6N, R3W on the east side of Red Creek, however, were described. In section 6, the Gypsum Spring is 182 feet (55.5 meters) thick and composed of interbedded white, massive gypsum, crinkled, gypsiferous, white, thick to thinly laminated limestone, red to gray shale, and white to pink sandstone. The Gypsum Spring of this central Wyoming namesake area represents only the basal middle Jurassic and correlates with lower member of Gypsum Spring as subsequently employed by U.S. Geological Survey parties in Montana and parts of the Bighorn basin in Wyoming (Imay, 1952).

The areal limits of the Gypsum Spring Formation have been revised by Imlay (1952, 1967, 1980), Francis (1956), Mapel and Bergendahl (1956), Skinner (1960) and Fox (1993). In 1967 and 1980, R.W. Imlay demoted the Gypsum Spring to the rank of basal member of Twin Creek Limestone in many areas. Fox (1993) locally identified this formation in the subsurface of the Powder River basin of Montana and Wyoming where it overlies the Chugwater Formation and unconformably underlies the Sundance Formation. The Gypsum Spring Formation (MT, SD, WY) or the Gypsum Spring Member of the Twin Creek Limestone (ID, UT, WY) are now recognized in the

Green River basin, the Powder River basin, the Snake River basin, the Uinta basin and uplift, the Wasatch uplift, the Wind River basin, and the Yellowstone province.

Paleontology

The marine-margin Gypsum Spring Formation is not notably fossiliferous. Wanless and others (1955) reported the presence of the bivalve mollusks *Pholadomya*, *Trigonia*, and *Astarte*. Wright (1974) compared this feeding association to the Jurassic bivalve mollusk associations of Wyoming and South Dakota.
In the Bighorn Basin, mega tracksites occur at multiple horizons within a four-foot (one-meter) interval in the middle part of the Gypsum Spring Formation (uppermost Bajocian in age) dating from about 170 MYBP (million years before the present) (Kvale and others, 2001a, 2001b; Mickelson and others, 2003, 2005). The terrestrial tracks are tridactyl and attributed to small- to medium-sized bipedal dinosaurs. At least some of these prints can be attributed to theropods. Both digit and heel impressions are preserved in some of the Gypsum Spring footprints. Swim tracks of crocodile and possibly bipedal dinosaurs are also present in the Gypsum Spring Formation (Mickelson and others, 2005, 2006). Estimates of dinosaur speeds based on foot size and stride ranging a high as 9.2 kilometers per hour have been calculated. The first major Gypsum Spring dinosaur tracksite was recognized in 1999 by Walter Parrs Jr., a New York City resident visiting a local ranch.

University of Wyoming Locality Search

A search of records was conducted at the University of Wyoming (UW) for known fossil localities by Dr. Michael Casilliano in December 2012. He noted that no localities occur in UW records from the formations of interest in Crook County, Wyoming, or anywhere in the Townships within which the reroutes are proposed.

Summary

Field paleontological and geological surveys have not been conducted in the study area. It is also not known with any certainty if bedrock outcrops are present at the surface or shallow subsurface. Mapping by Sutherland (2007) depicts the presence of bedrock of the Inyan Kara Group, Morrison Formation, Sundance Formation, and Gypsum Springs Formation underlying possible alternatives. Paleontological review documents that all these rock units are known to produce fossils of scientific interest and importance.

A locality search documented that no localities occur in UW records from the formations of interest in Crook County, Wyoming, or anywhere in the Townships within which the reroutes are proposed.

The Potential Fossil Yield Class for each of these geological units, as well as overlying surficial deposits, as interpreted by Dr. Winterfeld is provided below. Class 1 indicates there is no potential for fossils while class 5 areas have the highest potential.

Geologic Unit	Potential Fossil Yield Class	Potential mitigation
Land slide deposits	2	None
Colluvium	2	None
Inyan Kara Group	3	Survey, Inspect or monitor
Morrison Formation	5	Survey, Inspect or monitor
Sundance Formation	3	Survey, Inspect or monitor
Gypsum Springs Formation	3	Survey, Inspect or monitor

Recommendations

The thickness of overlying surficial deposits is not known with certainty and whether or not any of the geologic bedrock formations with paleontological potential will be disturbed by excavation. As a result, it is unknown at present if any mitigation for fossil resources should be applied.

A paleontological and geological field survey is recommended prior to any construction activities. This will determine the need for on-site monitoring of highway construction and materials evacuation into bedrock deposits.

Sincerely,

Gustav F. Winterfeld PhD, RG — 8 January 2013

Gustav F. Winterfeld, Ph.D., RG — Date

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